

AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions and listings of claims in the application.

1 1. (Currently Amended) A ~~computer-implemented~~ method of determining lower and  
2 upper bounds for a minimum cost of placing data objects onto nodes of a distributed  
3 storage system while meeting a performance requirement for a workload comprising  
4 the steps of:

5 solving an integer program using a relaxation of binary variables to  
6 determine the lower bound, the binary variables having values between zero  
7 and one comprising a first subset;

8 for the binary variables in the first subset and until no binary variables  
9 remain in the first subset, iteratively performing the steps of:

10 rounding up a first binary variable having a lowest ratio of a cost  
11 penalty to a performance reward; and

12 until no binary variables remain in a second subset, iteratively  
13 performing the steps of:

14 determining the binary variables in the first subset that may  
15 be rounded down without violating a performance constraint,  
16 thereby forming the second subset;

17 rounding down one or more second binary variables in the  
18 second subset having a zero performance reward; and

19 rounding down a third binary variable in the second subset  
20 having a highest ratio of a cost reward to the performance  
21 reward if none of the binary variables in the second subset have  
22 the zero performance reward; and

23 determining the upper bound according to the binary variables having  
24 binary values; and

25 placing the data objects onto the nodes of the distributed storage system  
26 using a data placement heuristic selected in accordance with the determined  
27 lower and upper bounds.

1 2. (Currently Amended) The ~~computer-implemented~~ method of claim 1 wherein the  
2 integer program comprises the performance constraint and an objective of minimizing  
3 a cost.

1 3. (Currently Amended) The ~~computer-implemented~~ method of claim 1 wherein the  
2 integer program models a data placement problem.

1 4. (Currently Amended) The ~~computer-implemented~~ method of claim 3 wherein the  
2 data placement problem seeks to minimize a cost of placing the data objects onto the  
3 nodes of athe distributed storage system while meeting athe performance requirement  
4 for athe workload.

1 5. (Currently Amended) The ~~computer-implemented~~ method of claim 1 wherein the  
2 step of rounding up the first binary variable within the first subset further comprises  
3 calculating the cost penalty and the performance reward.

1 6. (Currently Amended) The ~~computer-implemented~~ method of claim 5 wherein the  
2 step of rounding down the one or more second binary variables within the second  
3 subset further comprises calculating the performance reward.

1 7. (Currently Amended) The ~~computer-implemented~~ method of claim 6 wherein the  
2 step of rounding down the third binary variable within the second subset further  
3 comprises calculating the cost reward.

1 8. (Currently Amended) A ~~computer-implemented~~ method of determining bounds  
2 for a minimum cost comprising the steps of:  
3 solving an integer program using a relaxation of binary variables to  
4 determine a lower bound for the minimum cost, the relaxation allowing the  
5 binary variables to take values over the range of zero to one, a first subset of  
6 the binary variables comprising the binary variables having values between

7 zero and one, the integer program modeling a data placement problem which  
 8 seeks to minimize a cost of placing data objects onto nodes of a distributed  
 9 storage system while meeting a performance requirement for a workload;  
 10 until no binary variables remain in the first subset, iteratively performing  
 11 the steps of:  
 12 calculating a cost penalty and a performance reward for each of the  
 13 binary variables in the first subset;  
 14 rounding up a first binary variable having a lowest ratio of the cost  
 15 penalty to the performance reward;  
 16 until no binary variables remain in a second subset, iteratively  
 17 performing the steps of:  
 18 determining the binary variables in the first subset that may  
 19 be rounded down without violating the performance  
 20 requirement, thereby forming the second subset;  
 21 calculating a cost reward and the performance reward for  
 22 each of the binary variables in the second subset;  
 23 rounding down one or more second binary variables in the  
 24 second subset having a zero performance reward;  
 25 rounding down a third binary variable in the second subset  
 26 corresponding to a highest ratio of a cost reward to the  
 27 performance reward if none of the binary variables in the  
 28 second subset have the zero performance reward; and  
 29 determining an upper bound for the minimum cost according to the binary  
 30 variables having binary values; and  
 31 placing the data objects onto the nodes of the distributed storage system  
 32 using a data placement heuristic selected in accordance with the determined  
 33 lower and upper bounds.

- 1 9. (Currently Amended) The ~~computer implemented~~ method of claim 8 wherein the
- 2 integer program further comprises a storage constraint.

1 10. (Currently Amended) The ~~computer-implemented~~ method of claim 9 wherein the  
2 step of determining the upper bound for the minimum cost further comprises the steps  
3 of:

4 determining a particular node which uses a maximum amount of storage  
5 within any evaluation interval; and  
6 allocating the maximum amount of storage on all nodes for all evaluation  
7 intervals.

1 11. (Currently Amended) The ~~computer-implemented~~ method of claim 9 wherein the  
2 step of determining the upper bound for the minimum cost further comprises the steps  
3 of:

4 determining a maximum amount of storage for each node within any  
5 evaluation interval; and  
6 allocating the maximum amount of storage on each node for all evaluation  
7 intervals.

1 12. (Currently Amended) The ~~computer-implemented~~ method of claim 8 wherein the  
2 integer program further comprises a replica constraint.

1 13. (Currently Amended) The ~~computer-implemented~~ method of claim 12 wherein the  
2 step of determining the upper bound for the minimum cost further comprises the steps  
3 of:

4 determining a maximum number of replicas for any data object within any  
5 evaluation interval; and  
6 placing the maximum number of replicas for all data objects for all  
7 evaluation intervals.

1 14. (Currently Amended) The ~~computer-implemented~~ method of claim 12 wherein the  
2 step of determining the upper bound for the minimum cost further comprises the steps  
3 of:

4 determining a maximum number of replicas for each data object within

any evaluation interval; and  
 placing the maximum number of replicas for each data object for all  
 evaluation intervals.

15. (Original) A computer readable memory comprising computer code for  
 implementing a method of determining bounds for a minimum cost, the method of  
 determining the bounds for the minimum cost comprising the steps of:  
 solving an integer program using a relaxation of binary variables to  
 determine a lower bound for the minimum cost, the integer program  
 comprising a performance constraint and an objective of minimizing a cost,  
 the binary variables having values between zero and one comprising a first  
 subset;  
 for the binary variables within the first subset and until no binary variables  
 remain in the first subset, iteratively performing the steps of:  
 rounding up a first binary variable having a lowest ratio of a cost  
 penalty to a performance reward; and  
 until no binary variables remain in a second subset, iteratively  
 performing the steps of:  
 determining the binary variables in the first subset that may  
 be rounded down without violating the performance constraint,  
 thereby forming the second subset;  
 rounding down one or more second binary variables in the  
 second subset having a zero performance reward; and  
 rounding down a third binary variable in the second subset  
 having a highest ratio of a cost reward to the performance  
 reward if none of the binary variables in the second subset have  
 the zero performance reward; and  
 determining an upper bound for the minimum cost according to the binary  
 variables having binary values.

16. (Original) The computer readable memory of claim 15 wherein the integer

2 program models a data placement problem.

1 17. (Previously Presented) The computer readable memory of claim 16 wherein the  
2 data placement problem seeks to minimize a cost of placing data objects onto nodes  
3 of a distributed storage system while meeting a performance requirement for a  
4 workload.

1 18. (Previously Presented) The computer readable memory of claim 15 wherein the  
2 step of rounding up the first binary variable within the first subset further comprises  
3 calculating the cost penalty and the performance reward.

1 19. (Previously Presented) The computer readable memory of claim 18 wherein the  
2 step of rounding down the one or more second binary variables within the second  
3 subset further comprises calculating the performance reward.

1 20. (Previously Presented) The computer readable memory of claim 19 wherein the  
2 step of rounding down the third binary variable within the second subset further  
3 comprises calculating the cost reward.

1 21. (Original) A computer readable memory comprising computer code for  
2 implementing a method of determining bounds for a minimum cost, the method of  
3 determining the bounds for the minimum cost comprising the steps of:  
4 solving an integer program using a relaxation of binary variables to  
5 determine a lower bound for the minimum cost, the relaxation allowing the  
6 binary variables to take values over the range of zero to one, a first subset of  
7 the binary variables comprising the binary variables having values between  
8 zero and one, the integer program modeling a data placement problem which  
9 seeks to minimize a cost of placing data objects onto nodes of a distributed  
10 storage system while meeting a performance requirement for a workload;  
11 until no binary variables remain in the first subset, iteratively performing  
12 the steps of:

calculating a cost penalty and a performance reward for each of the  
 binary variables in first the subset;  
 rounding up a first binary variable having a lowest ratio of the cost  
 penalty to the performance reward;  
 until no binary variables remain in a second subset, iteratively  
 performing the steps of:  
     determining the binary variables in the first subset that may  
     be rounded down without violating the performance  
     requirement, thereby forming the second subset;  
     calculating a cost reward and the performance reward for  
     each of the binary variables in the second subset;  
     rounding down one or more second binary variables in the  
     second subset having a zero performance reward;  
     rounding down a third binary variable in the second subset  
     corresponding to a highest ratio of a cost reward to the  
     performance reward if none of the binary variables in the  
     second subset have the zero performance reward; and  
 determining an upper bound for the minimum cost according to the binary  
 variables having binary values.

22. (Original) The computer readable memory of claim 21 wherein the integer  
 program further comprises a storage constraint.

23. (Original) The computer readable memory of claim 22 wherein the step of  
 determining the upper bound for the minimum cost further comprises the steps of:  
     determining a particular node which uses a maximum amount of storage  
     within any evaluation interval; and  
     allocating the maximum amount of storage on all nodes for all evaluation  
 intervals.

24. (Original) The computer readable memory of claim 22 wherein the step of

2 determining the upper bound for the minimum cost further comprises the steps of:  
3 determining a maximum amount of storage for each node within any  
4 evaluation interval; and  
5 allocating the maximum amount of storage on each node for all evaluation  
6 intervals.

1 25. (Original) The computer readable memory of claim 21 wherein the integer  
2 program further comprises a replica constraint.

1 26. (Original) The computer readable memory of claim 25 wherein the step of  
2 determining the upper bound for the minimum cost further comprises the steps of;  
3 determining a maximum number of replicas for any data object within any  
4 evaluation interval; and  
5 placing the maximum number of replicas for all data objects for all  
6 evaluation intervals.

1 27. (Original) The computer readable memory of claim 25 wherein the step of  
2 determining the upper bound for the minimum cost further comprises the steps of;  
3 determining a maximum number of replicas for each data object within  
4 any evaluation interval; and  
5 placing the maximum number of replicas for each data object for all  
6 evaluation intervals.